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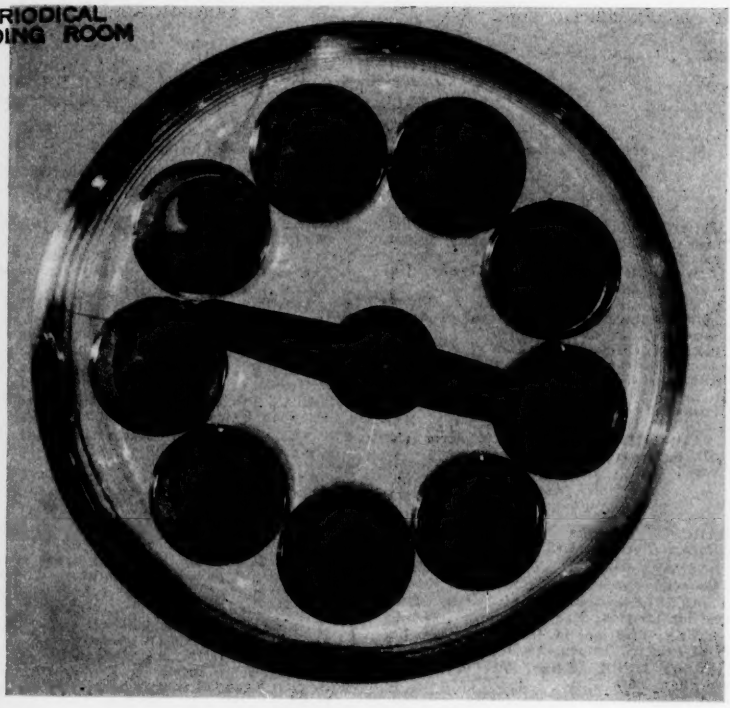

POLLEN WITH MUSTARD
(SEE PAGE 232)

Tailed Men, Stumpy Cows and Pygmy Mice

Recessive Whorls in Cocker Spaniels

Cytological Effects of Antibiotics

Varied Reactions to Thiouracil

VOLUME 41 SEPTEMBER, 1950 NUMBER 9

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The

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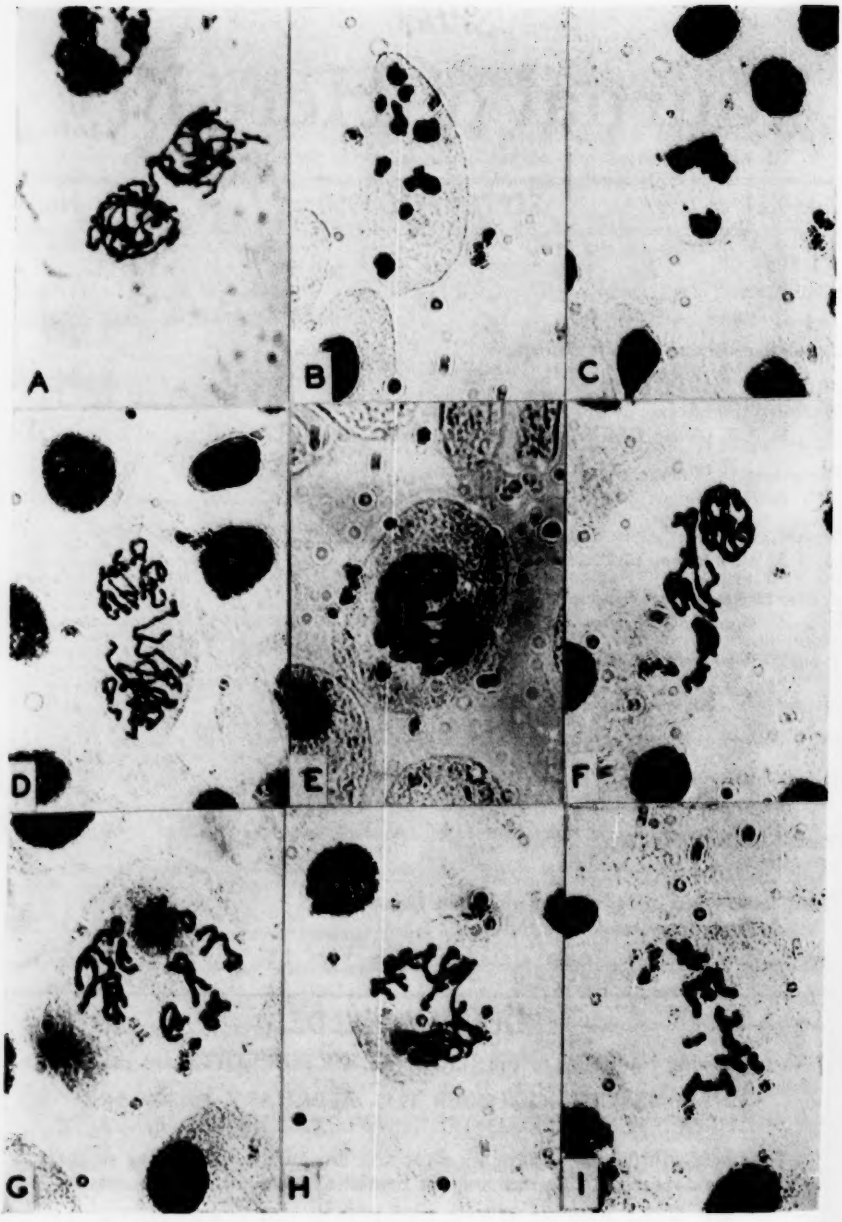


CYTOLOGICAL EFFECTS OF PENICILLIN, STREPTOMYCIN, NEOMYCIN AND ENDOMYCIN ON *ALLIUM CEPA*.

Figure 1

A—'Reductional grouping' at prophase from root tip treated with 100 ppm Penicillin G for 60 hours. *B*, *C* and *D*—From root tips treated with Streptomycin showing individual chromosomes reverting to resting stage, unbalanced telophase and 'reductional' prophase. *E*, *F* and *G*—Two 'reductional' prophases and a 'reductional' pro-metaphase from roots treated with 6 ppm Neomycin for 12 hours. *H* and *I*—'Reductional' pro-metaphase and metaphase from Endomycin treated roots.

CYTOLOGICAL EFFECTS OF SOME ANTIBIOTICS

G. B. WILSON*

DURING the past few years it has increasingly become the fashion to spray, dust or inject the living world with a disconcerting array of organic chemicals, some synthetic and some themselves the metabolic products of living organisms. The purpose behind this unprecedented assault is control of pests. The criterion which determines whether or not a given chemical may be used is relatively simple; if it kills or seriously damages the pest without killing or obviously damaging the host or other economic organisms with which it may come in contact, it is considered suitable, assuming that the cost of application is not unduly excessive. This, so far as it goes, appears to be an adequate screening technic. However, the possibility always remains that any of these substances may have cytological and/or genetical effects even at concentrations that are considered sub-lethal.

Through the generous co-operation of the Upjohn Company of Kalamazoo, Michigan, and Dr. John Vaughn of this department, it recently became possible to carry out some exploratory studies with a series of antibiotics. The present paper is chiefly concerned with the general cytological effects found during the course of these preliminary studies.

Most of the work has been carried out on roots of *Allium cepa*. Bulbs were rooted in tap water and subsequently transferred to solutions of the antibiotics concerned, after sample roots had been fixed to determine initial "normality." Tap water and distilled water controls were also run. Since these showed no detectable differences, the antibiotics were usually dissolved in distilled water. Most preparations were made by the Feulgen squash technic.

Observations

1. Penicillin G

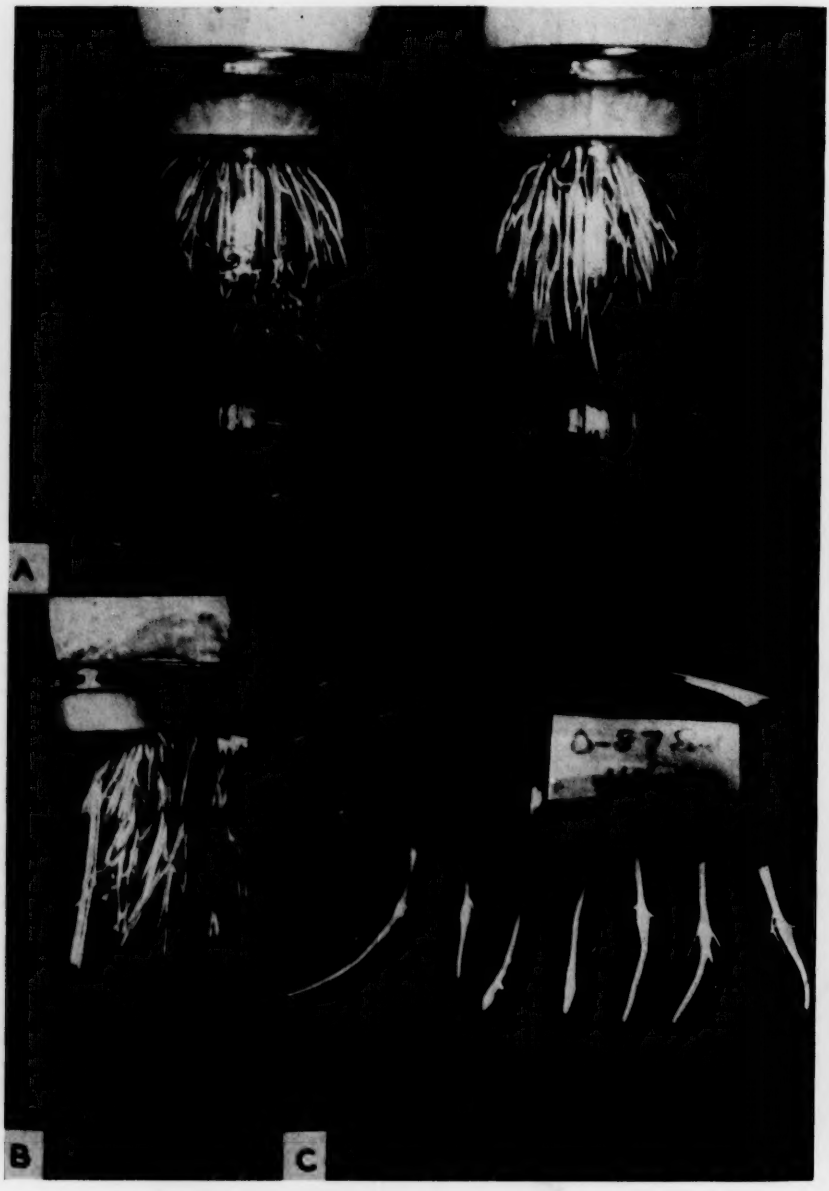
Penicillin G is a metabolic by-product of certain strains of *Penicillium notatum* and *P. chrysogenum*. In the present case the crystalline potassium salt dissolved in distilled water was used in concentrations of 100, 200, 400, and 800 ppm† for times ranging from twelve hours to seven days. Very few mitotic aberrations were found at any concentration for any time. Two observations, however, seem worthy of further consideration: (a) up to 200 ppm there appears to be more mitotic activity than normally found in controls and (b) prophase 'reductional groupings'[3,4] were relatively frequent (Figure 1*A*).

2. Streptomycin

Streptomycin is produced by *Streptomyces griseus*. In the present instance it has been used in the form of the sulphate at concentrations ranging from 50 to 200 ppm. At the lower concentrations it has little obvious cytological effect but in doses over 100 ppm it appears to be relatively toxic and also upsets the mitotic apparatus. Resting nuclei appear to be more or less fibrous and division figures, especially at pro-metaphase and metaphase show clumping and stickiness. In some division figures, the chromosomes are very short and have a texture indicating reversion to resting stage as individual chromosomes (Figure 1*B*). Likewise anaphase separation may be irregular (Figure 1*C*). At all concentrations used the chromosomes tend to be markedly shorter at full metaphase than in controls and there is also a higher frequency of "reductional' prophases (Figure 1*D*).

*Associate Professor of Botany, Michigan State College, East Lansing, Michigan. The author wishes to express his indebtedness to: The All-College Research Committee for financial assistance; Mr. Philip Coleman, who prepared the plates; Mr. J. F. Delaney, who carried out most of the experiments; Miss Carol Kazahn, who made some of the preparations; Miss Marilyn Huston for contributing unpublished data on the effects of Streptomycin and Messrs. C. C. Bowen and Wm. Klomparens for running preliminary experiments on rye and bent grass seedlings respectively. Contribution No. 50-1 of the Department of Botany and Plant Pathology, Michigan State College, East Lansing, Michigan.

†Ppm means "parts per million."



MORPHOLOGICAL EFFECTS OF NEOMYCIN, PENICILLIN AND ENDOMYCIN ON *ALLIUM* ROOTS

Figure 2

A—Bottle 75 contains 6 ppm Neomycin. Note attenuated regions back of the meristem. Bottle 79 contains 800 ppm Penicillin which had no detectable morphological effect within seven days. *B*—Bottle contains 100 ppm Endomycin. Roots have been treated for approximately seven days. Note colchicine-like swellings. *C*—Isolated roots four days later show side roots coming off from top of swelling.

3. Neomycin

Neomycin is obtained from *Streptomyces fraedii*. It has been used in the current experiments in the form of its sulphate in concentrations ranging from 100 ppm down to 6 ppm. In general, it appears to be highly toxic. Even at the lowest concentration used, most roots show a somewhat hyaline attenuated region back of the meristem within twelve hours (Figure 2*A*). Below 25 ppm there appear to be relatively few obvious cytological deviations from "normal." Above that concentration there are usually very few division figures and those found generally show the typical poison effect of clumping and stickiness. At all concentrations, however, the chromosomes tend to be shorter than normal at metaphase and there is a relatively high frequency of "reductional" type prophases and pro-metaphases (Figures 1*E-G*).

4. Circulin

Circulin is an antibiotic derived from *Bacillus circulans*. It has so far been used at concentrations ranging from 100 ppm down to 12 ppm. It is highly toxic and the morphological symptoms thereof are similar to those described for Neomycin. Very few division figures were found at any concentration after twelve hours but the few which did appear seemed to be more or less normal with regard to organization.

5. Endomycin

Endomycin is derived from *Streptomyces sp.* and has so far been available only in the form of the crude extract rated at 10-20 percent active ingredient. It has been used only at concentrations of approximately 100 ppm based on the estimate of antibiotic content. So far few indications of cytological aberration have been noted. There is a tendency for the chromosomes to be somewhat shorter than normal and more indications of prophase 'reductional groupings' have been found than generally encountered in untreated controls (Figure 1*H-I*). The most interesting reaction noted to date is on the type of root growth itself. Root elongation is greatly retarded and swellings, reminiscent of those induced by colchicine, appear back of the growing point (Figure 2*B*). Subsequently one or more branch roots may appear, usually arising from the top of the swelling (Figure 2*C*).

6. Actidione

Actidione, like Streptomycin, is produced by *S. griseus*.[2,5] This antibiotic has pronounced fungicidal properties[8,9] but whether or not its toxicity to plants and animals will preclude its commercial use has yet to be fully determined. From the cytological point of view, it is one of the more interesting antibiotics yet investigated since it readily and consistently induces specific aberrations in mitotic behavior. The more easily classifiable effects may be summarized as follows: a. "super contraction" of the chromosomes (prolongation of prophase ?). After 24 hours' exposure to 100 ppm "metaphase" chromosomes are about 1/3 the length found at full metaphase in untreated materials (Figures 3*A-B*). b. Lack of organization of the metaphase plate (Figures 3*A-B*). c. Disorganization of anaphase separation ranging from lagging chromosomes (Figure 3*C*) to apparently completely random distribution of chromatids. d. Formation of 'reductional groupings' of the type found by Huskins and his associates[3,4,10] after sodium nucleate treatment (Figures 3*D-E*). Concentrations ranging from 1 to 200 ppm were effective and from 5 ppm up, almost every division figure past prophase was aberrant in one or more of the ways indicated.

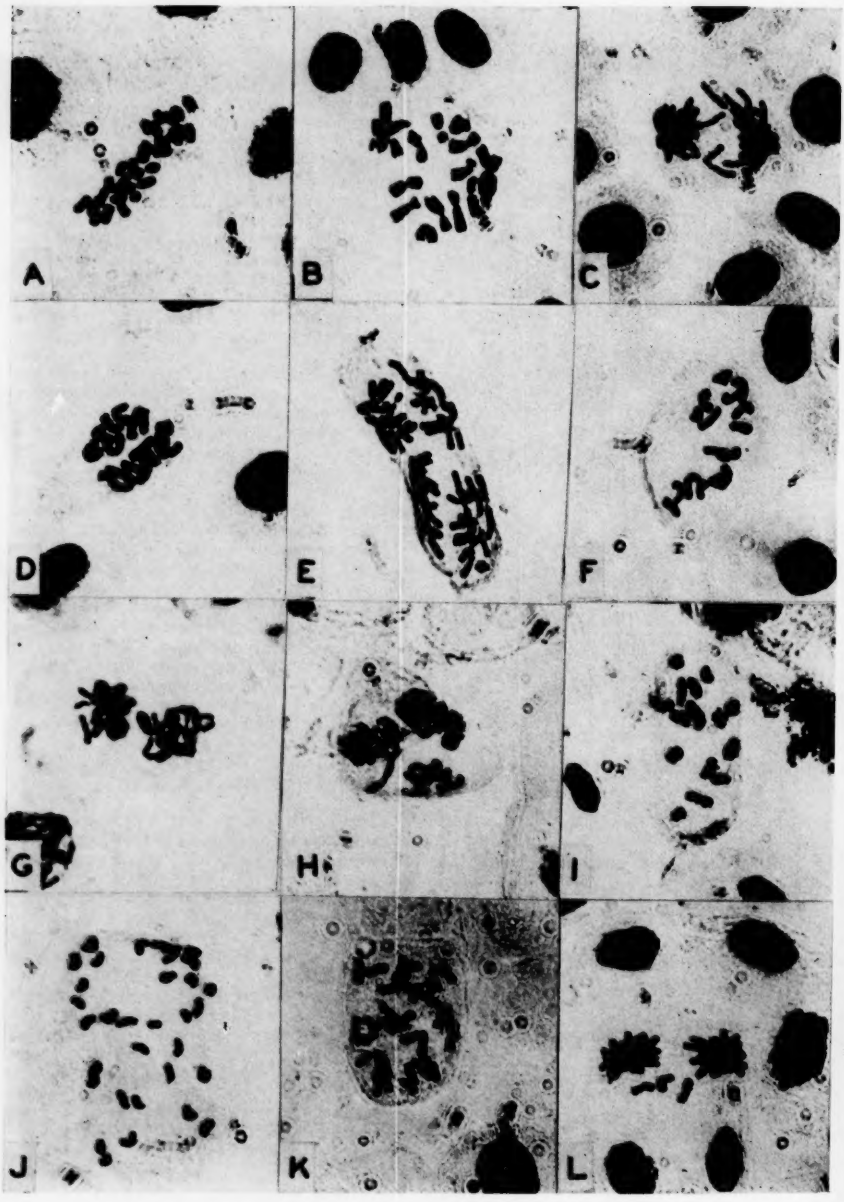
In order to determine the survival value of the aberrations noted, some recovery experiments were attempted. To date none of these has been successful. Careful and prolonged washing of treated bulbs followed by transfer to clean tap water not only fails to induce recovery in affected roots but rather the deviations continue to be intensified much as if the change had not been made. This would seem to indicate high retention of the active substance. Similar effects have been noted in treating rye and bent grass seedlings. Furthermore, there is some evidence that little if any translocation of the substance occurs since the shoots of such seedlings show no detectable effect while the roots are highly affected.

7. Streptothricin

Streptothricin is produced by *Streptomyces lavendulae* and has so far been used as the sulphate. From the cytological point of view its reactions are very similar to those of Actidione (Figures 3*G-L*). It differs in one respect, however, in that it appears to be unstable in solution. A concentration of 50 ppm which, in fresh solution is more effective than 200 ppm Actidione, is almost completely innocuous after several days. This antibiotic has not been available in sufficient quantities to allow for any very extensive experiments so that it has been impossible to date to investigate the possibilities of "recovery." On *a priori* grounds one might hope for better success than with Actidione.

Discussion

At this stage any prolonged and detailed discussion of results and their significance would be futile to say the least. We have so far been concerned with the question of whether or not a given antibiotic has demonstrable cytological effects and if so, what kind. All of the



CYTOLOGICAL EFFECTS OF ACTIDIONE AND STREPTOTHRICIN ON *ALLIUM CEPA*

Figure 3

A to *F*—Cells from roots treated with Actidione at various concentrations. *A* and *B* show short chromosomes and failure of metaphase. *C* shows lagging chromosomes at anaphase. *D*, *E* and *F* show 'reductional groupings.' *E* is an anaphase 'reductional grouping' of 9-9/7-7. *G* to *L*—results of treatment with Streptothricin. *G*—"reductional" prophase; *H*—three group separation; *I*—"metaphase" 'reduction'; *J*, *K* and *L*—disorganized anaphases.

antibiotics used have given indications of inducing 'reductional groupings'* but only two, Actidione and Streptothricin, have been found to produce marked deviations from the typical order. The two most significant variations from both the academic and practical points of view would appear to be the failure of the metaphase-anaphase sequence and the induction of 'reductional groupings.' The former is a situation which could, in theory, lead to polyploidy as realized in the case of colchicine and similar drugs while the latter could, as pointed out by Huskins and his co-workers,[3,4] lead to both genetic segregation and "haploidy." Neither of these possibilities has yet been demonstrated to occur so that they remain only as potentialities of which we should be fully aware without, at the same time, giving them the weight of foregone conclusions.

Of particular interest is the finding of 'reductional' type division figures induced by substances in no way related to those previously used.[1,3,4,10] This would seem to eliminate any possibility that nucleic acid or the phosphate radical thereof is directly involved. The work on colchicine-induced separations[6] does not fully undermine this hypothesis since they differ in several respects from those typical of sodium nucleate-treated materials.[1] It is probably to the point that the present author cannot distinguish between an "Actidione" and a "sodium nucleate" slide but has always been able to pick out a "colchicine" slide from either.

In addition to further exploratory work, considerable detailed studies remain to be made especially with regard to frequencies of various types of abnormalities and recovery. Some of these studies are now in progress and to avoid bias, in so far as possible, experiments have been so arranged that the experimenter is unaware of the treatments used since both solutions and slides are coded by someone else.

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*The term 'reductional grouping' is according to the usage of the Wisconsin group. In my opinion it is not an altogether happy choice since it implies more than has been unequivocally accomplished to date. It has, however, been established in the literature and nothing is to be gained by further confusing the issue through the invention of a new term. Whatever the genetic implications, the point of paramount importance to the cytologist is the possibility of unmasking forces inherent in the nucleus and the chromosomes with the hope that we may be brought one short step nearer the solution of the vexatious problem of the mechanics of mitosis (Cf. Schrader, 1944).

THE MUTAGENIC ACTION OF MUSTARD GAS ON *ZEA MAYS*

P. B. GIBSON, R. A. BRINK AND M. A. STAHMANN*
University of Wisconsin

A NEW phase in the study of mutation began with the discovery by Auerbach and Robson[1] in 1946 that the mustard gases are effective in inducing heritable changes in the germplasm. The proven mutagenic tools previously had been limited to X-rays and certain other kinds of radiations. A group of strongly active chemical substances was now added to the list and the possibility foreshadowed that with the broadening of this approach a higher level of control over mutation than was possible heretofore might be attained.

The present investigation is concerned with methods of applying mustard vapor in graded doses to maize pollen and with a preliminary analysis of the kinds of genetic changes induced in the plant by a particular nitrogen mustard, methyl-bis (*B*-chloroethyl) amine.

Methods and Materials

The initial series of experiments with mustard vapor involved exposure of the freshly collected pollen to the chemical for varying lengths of time in a small dessicator equipped with a magnetically operated fan. The air within the vessel was circulated over a filter paper moistened with enough of the mustard to approximately saturate it. Very few seeds were obtained from pollen which had been exposed to the saturated vapor for longer than two minutes. An apparatus was then devised which permitted of varying both the vapor concentration and the duration of exposure to the nitrogen mustard.

This apparatus, which is pictured in Figure 4, consisted of a drying tube containing a layer of calcium chloride and one of soda lime, a 22 cm. U-tube filled with small glass helices covered with methyl-bis (*B*-chloroethyl) amine, a mercury-filled burette, and a 500 milliliter treatment chamber. Dry air at the atmospheric temperature was drawn through the U-tube where it became practically saturated with nitrogen mustard vapor. Measured quantities of the air-vapor mixture were then introduced through the gas burette into the treating chamber (Figure 6) containing a filter paper moistened with water and a magnetically operated fan. The blade of the fan was so placed that the air-vapor mixture would be forced by it down the inside wall on one side of the 2 cm. shallow glass vials each containing 2 ml. of pollen spread over the bottom.

The first procedure outlined above in which the pollen was exposed in the dessicator to the saturated vapor of the mustard may be referred to as the "saturated vapor" method. The second procedure in which measured quantities of the saturated vapor were introduced into the treatment chamber is designated the "diluted vapor" method.

Except for a limited number of pollinations on a multiple recessive tester stock, an inbred line of yellow dent corn was used as the pistillate parent in the experiments with saturated mustard vapor. This stock had colorless aleurone, yellow endosperm, and was non-sugary (*A c r Pr Y Su*). Five inbreds were used as the staminate parents, one of which was the above mentioned yellow dent line. The other four had colored aleurone and white endosperm (*A C R y*). Two of the pollen lines had red aleurone (*pr*), and one was sugary (*su*). Some contamination from free pollen is unavoidable in experiments of this kind. An incomplete but reasonably effective control over this source of error was afforded by noting the composition of the F_1 and F_2 endosperms for these clear-cut marker characters. Data were taken in the series of tests on (1) fertility of the F_1 and F_2 plants in terms of aborted pollen and incompletely filled ears and (2) occurrence of chlorophyll defects among F_2 seedlings.

The pollen source in the diluted vapor experiments were S_1 plants from a selfed *a C R*^{t} *Pr Su Sh Wx B lg*$_1$ individual. The stock used as the pistillate parent, kindly supplied by Dr. L. J. Stadler, University of Missouri, was of the composition *A C r*^{g} *pr su* (or *Su su*) *sh wx b Lg*$_1$. Information was

*Paper from the Departments of Genetics (No. 415) and Biochemistry, College of Agriculture, University of Wisconsin. The senior author's present address is Department of Agronomy & Soils, Alabama Polytechnic Institute, Auburn.

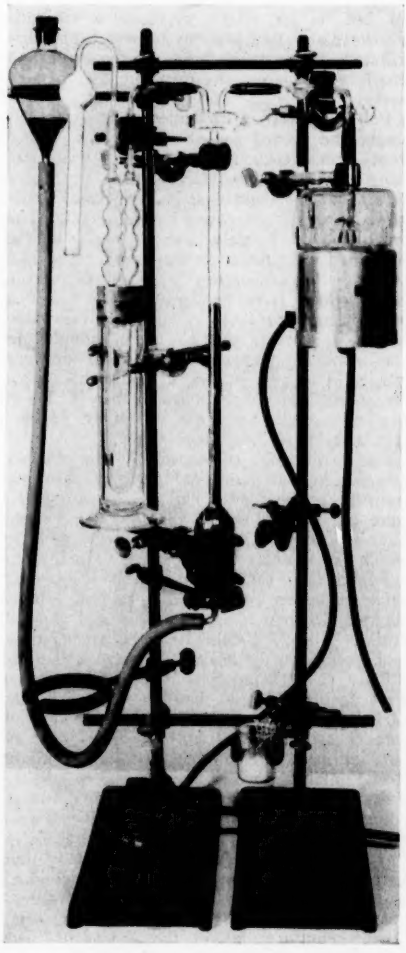
sought from the tests involving these stocks on the kinds of genetic changes induced by mustard treatment as inferred from (1) the effects on pollen and seed formation and (2) the distribution in F_1 and F_2 of the marked endosperm characters. The dominant genes affecting endosperm characters whose behavior under the treatments could be followed were *R*^{r}, *Pr*, *Su*, *Sh* and *Wx*. The respective contrasting effects in the mature kernels of the alleles represented are colored *vs* colorless aleurone, purple *vs* red aleurone, smooth *vs* wrinkled endosperm, plump *vs* shrunken endosperm, and normal *vs* waxy endosperm starch. The first mentioned character in each case is dominant.

B, a dominant intensifier for anthocyanin plant color, and the recessive gene *lg*^{1} (liguleless) were used in the identification of contaminants arising from the action of extraneous pollen. The diluted vapor treatments were given rather late in the season after most of the other strains being grown were past the pollen shedding stage. The most frequent source of contamination proved to be the pistillate stock itself. Kernels of this origin, however, could be recognized readily by the multi-recessive condition of the endosperm. Furthermore, the data from any progenies carried to the F_2 which failed to segregate for liguleless were excluded from the computations.

Mustard treatments of seven degrees of severity were selected on the basis of preliminary tests designed to determine the usable range. The air-vapor mixture introduced into the treating chamber varied from one to 24 milliliters and the exposure time of the pollen from one to five minutes. The treatments may be expressed as products of the milliliters of air-vapor mixture and the exposure time in minutes as follows: (1) 1 ml $\times$ 1 min; (2) 3 ml $\times$ 1 min; (3) 6 ml $\times$ 1 min; (4) 6 ml $\times$ 2.5 min; (5) 6 ml $\times$ 5 min; (6) 12 ml $\times$ 5 min; and (7) 24 ml $\times$ 5 min. The treatments were given in individual vials each containing 0.2 ml. of pollen. Each ear shoot received the contents of a single vial, and the pollinations were usually completed within fifteen minutes after treatment. Our experience shows that the most convenient method of treatment is to hold the time at five minutes and vary only the amount of mustard.

Results With Saturated Mustard Vapor

Pollen was exposed to saturated mustard vapor for ½, 1, 2, 4, 8, 16 and 32 minutes and then applied to the silks of normal plants. Many of the resulting kernels were shrivelled in varying degrees at maturity. The ears representing treatments longer than two minutes were nearly barren. The shrivelling appeared to be mainly a consequence of impaired endosperm development since many of the undersized seeds proved to be germinable and the ensuing plants, once past the seedling stage, often grew vigorously. The F_1 seeds were separated roughly into two lots before planting, one of which was half-size and above and the other below half-size. A total of 984 adult F_1 plants were obtained,



MUSTARD GAS APPLICATOR

Figure 4

The apparatus used to treat maize pollen with mustard gas vapor is shown here. The treatment chamber containing the pollen cups is at the upper right.

all but 41 of which represented mustard treatments of two minutes or less. The distribution of plants in terms of the large and small seed classes was 697 and 287, respectively.

Pollen samples were collected from the F_1 plants and scored for aborted grains. Since most deficiencies, inversions and translocations give rise to defective pollen, the latter serves as a collective index of gross structural changes in the chromosomes. The proportion of partially sterile plants in the entire treated population was found to be 14.5 percent. The frequency of partially fertile plants reared from the larger seeds was 10.9 percent, and from the small seeds the value was 23.3 percent. All 68 plants sampled in the control (untreated) progenies were fertile. The percentages of individuals producing aborted pollen following the ½, 1 and 2 minute treatments were 9 percent, 13 percent and 19 percent, respectively.

Many of the chromosomal disturbances detected in the immediate progeny resulting from the application of mustard treated pollen were not transmitted to the next generation. Seventy-one families from selfed partially fertile F_1 plants were grown. About ten individuals in each family were scored for defective pollen by estimating, without counting, the proportion of subnormal and aborted grains. The 71 families may be arranged in four groups on the basis of the pollen classification: (a) 23 families in which all plants were fertile, (b) 20 families in which the partially sterile individuals formed about 50 percent aborted or defective pollen, (c) 24 families in which the one or more partially sterile plants present showed considerably less than 50 percent aborted or defective pollen and (d) four mixed families, containing partially sterile plants of the types in (b) and (c). In 32 of the 48 segregating families only one partially sterile individual was found. That is to say, in 55, or three-quarters, of the 71 families the chromosomal derangement present in the parent F_1 was transmitted either not at all or with very low frequency. The frequencies of families containing 2, 3, 4 and 5 partially sterile plants were 2, 6, 3 and 5, respectively. Even though no cytological information was obtained which would aid in the interpretation of the sterility data, it seems clear that most of the chromosomal derangements induced by the mustard treatment are of self-eliminating types. Many of them are probably primary deficiencies. Further tests are required to determine whether any reciprocal translocations were present. If such occurred, their frequency was low relative to other kinds of structural changes.

Five families among 745 tested from selfed F_1 plants segregated for seedling chlorophyll defects. This is a frequency of 0.67 percent. No chlorophyll defects were found among the 49 control families grown. A subsequent planting of 300 kernels each of four of the segregating progenies from fully fertile ears gave 20.0 percent, 22.6 percent, 25.6 percent and 26.6 percent chlorophyll deficient seedlings, respectively. The fifth family, from a partially filled ear, was represented by 47 plants of which 10 were chlorophyll deficient. The number of control plants tested is too small to permit a definite conclusion on the basis of these data alone regarding the effect of the mustard treatment on mutation rate for chlorophyll defects. Assuming, however, that the chlorophyll deficiencies observed were due to point mutations resulting from the mustard treatment, it will be noted that their frequency is low in relation to that of chromosomal derangements.

Results With Diluted Mustard Vapor

Maize pollen is so rapidly killed by mustard gas that the dosage cannot be satisfactorily regulated when a saturated vapor is applied. This difficulty was overcome by using the equipment shown in Figure 4 in which the concentration of mustard in the air-vapor mixture can be attenuated to any desired degree.

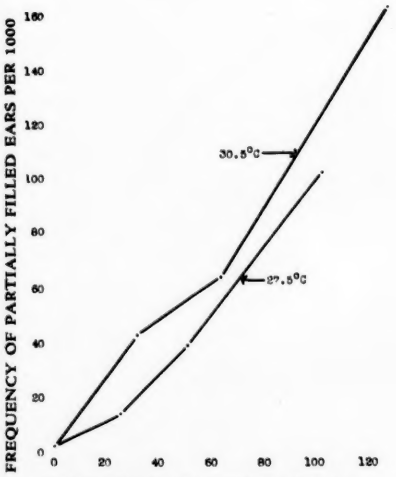
Dosage in Relation to Partial Sterility

The volatility of mustard gas varies with the temperature. From the most reliable volatility data available, it was estimated that one cubic centimeter of dry air saturated with the nitrogen mustard contains 4.25 and 5.30 micrograms, respectively, at 27.5° and 30.5° C. These were the air temperatures prevailing when the two sets of treatments were run (Table I). The treatments applied were numbers 5, 6 and 7 in which the volumes of the air-vapor mixture introduced into the 500 ml. chamber were 6, 12 and 24 ml., respectively. The duration of exposure of the pollen to the nitrogen mustard was five minutes in each case. The F_1 plants were scored for fertility by examination of the mature ears.

As the results summarized in Table I and

TABLE I.—Relation between dosage of nitrogen mustard and frequency of partially fertile F_1 plants

Air temperature	Micrograms of nitrogen mustard	Number of F_1 plants		Partially fertile plants per 1000
		Total	Partially fertile	
27.5° C.	0	1089	3	2.7
	25.5	984	14	14.2
	51.0	887	35	39.5
	102.0	563	58	103.0
30.5° C.	0	1096	3	2.7
	31.8	877	38	43.3
	63.9	621	40	64.4
	127.2	61	10	163.3



EFFECT OF DOSAGE ON FERTILITY

Figure 5

The graph shows the relation between concentration of mustard gas used in the treatment and frequency of partially sterile F_1 plants derived from treated pollen.

charted in Figure 5 show, the relation between concentration of the nitrogen mustard and number of partially fertile F_1 plants per thousand scored is approximately linear over the range tested.

Losses in the F_1 Endosperm of Dominant Marker Characters

The data bearing on the frequency of loss in the F_1 endosperm of the phenotypic effects of the dominant alleles *Su*, *Wx*, *Sh*, *Pr* and *R* in relation to dosage of mustard are summarized in Table II. The results are based upon a single run on a common collection of pollen which was subdivided for the three mustard treatments and the untreated control. The experiment was repeated on two other occasions. An incomplete set of ears was obtained in one series due to disease. The other test yielded results very similar to those presented in the table.

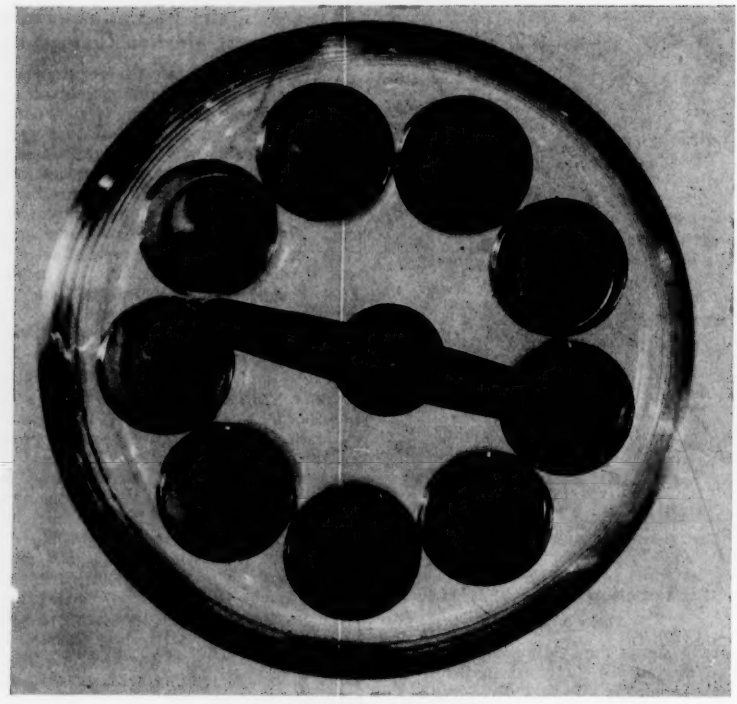
The kernels showing losses of the specified kinds were separated into two categories, "entire" and "fractional," depending on whether the whole or only a part of the endosperm was affected. No attempt was made to score fractional *R*-losses because of the irregular mottling characteristic of normal *Rrr* endosperms. The data relating to the *sh* locus are of rather uncertain dependability due to the prevalence throughout the stock used of more or less "denting" of the kernels and a decision not to split the seeds in classification and thus render them useless for propagation. Fractional losses for *Sh* were not recorded for the same reasons. It is believed that satisfactory accuracy was achieved in scoring losses involving the other marked loci. F_2 plants were grown out from the controls and the viable seeds obtained following application of pollen given the three mustard treatments 5, 6 and 7. The data in Table II are based on F_1 kernels from which F_2 offspring were obtained.

Among the 1089 control kernels a total of ten losses for the marked endosperm characters occurred. All of these involved the *Pr* locus, and in each case only a part of the

TABLE II.—The frequency of loss of dominant characters in the endosperm following treatment of pollen with nitrogen mustard at 27.5°C.

Treatment	Control	5 (6ml × 5min)	6 (12ml × 5min)	7 (24ml × 5min)
Number ears classified	3	4	4	4
Number of kernels				
Classifiable	1089	868	798	418
Unclassifiable	0	6	44	55
Showing marker gene losses				
Su entire	0	10	27	24†
fractional	0	22	40	26†
Wx alone, entire	0	0	0	6
Wx & *Sh*, entire	0	10	9	13
Wx fractional	0	11	30	11
Pr entire	0	17	34	33
fractional	10	66	85	74
R entire	0	11	31	30
Kernels exhibiting multiple losses × 2*	0	18	62	18
Total marker losses	10	165	318	235
Percent losses on total classifiable kernels	0.9	19.0	39.8	56.2

*Each multiple loss counted as two losses.
†Loss of *Su* multiplied by 2 to correct for *Su su* female parent.



TREATMENT CHAMBER

Figure 6

This photograph shows the treatment chamber with the pollen cups in place . The uniform distribution of the mustard gas vapor is assured by the small fan which is magnetically operated. Approximately natural size.

endosperm lacked the phenotypic effect characterizing the dominant allele. The reason for the relatively high rate of spontaneous mutation for *Pr* in this stock is not known.

It will be noted from Table II that at all three treatment levels the frequency of losses of the marked endosperm characters is much higher than in the controls. At treatments 5 and 6 the number of losses is directly proportional to dosage. At treatment 7 the frequency of losses is still higher but the rate falls off sharply relative to dosage.

Although the data concerning *Sh* are subject to some reservation because of classification difficulties, nearly all *Wx*-losses, as Table II shows, appeared to involve the loss of *Sh* also. There were 32 such double losses as compared with six of waxy alone and one doubtful loss of *Sh* alone (not shown in table). The *Sh* locus is distal to *Wx* on the same arm of chromosome 9.

Entire and Fractional Losses

Losses affecting only a part of the endosperm greatly exceed those characterizing the whole tissue. The relevant data are summarized in Table III. The numbers of fractional losses for *Su* and *Wx* are 1.4 times those for the respective entire losses, and the ratio is about twice as high for *Pr*. In a supplementary experiment made to check the proportion of entire to fractional losses, treatments 5, 6 and 7 were given to A_1A_2C *R* pollen which was then applied to the silks of a_1a_2c *R* plants. Classification of 4647 kernels revealed 750 fractional losses of aleurone pigmentation and 186 entires, or a ratio of 4:1.

The F_2 Generation

The ears from 1264 self-pollinated F_1 plants, comprising 331 controls and 933 in-

dividuals distributed over mustard treatments 5, 6 and 7, were scored for *Su, Wx, Sh, Pr* and *R* losses. Mutations for endosperm characters induced in the sperm which fertilize the egg rather than the central cell of the female gametophyte are disclosed in this generation. *A priori* it might be expected that the results in the F_1 and F_2 endosperms would be comparable since, on the average, the two series of sperm involved are equally exposed in the pollen to the nitrogen mustard. The facts, however, are quite the contrary.

One mutation to waxy (*wx*) and one *R*-loss appeared in the control population. The F_1 plant and ear bearing the waxy mutation was otherwise indistinguishable from the remaining controls, and a family grown from 16 selfed seeds confirmed the presence of liguleless, the recessive marked character of the staminate parent. The F_1 control plant showing the *R*-loss was partially fertile.

Among the 933 ears in the mustard treated series two *R*-losses were found, one of them on a partially filled ear. No other losses of the five dominant endosperm characters were recovered. This is a frequency of .21 percent as compared with .60 percent in the control group. It may be recalled at this point that about 12 percent of the F_1 endosperms in treatments 5, 6 and 7 showed entire losses of the same marker characters.

Discussion and Conclusions

The evidence presented on the incidence of partially fertile plants shows that treatment of maize pollen with nitrogen mustard vapor is highly effective in causing chromosome breakage. Pollen subjected to an atmosphere approximately saturated with the substance for one-half to two minutes (treatments which approach the lethal dose) yielded offspring 14.5 percent of which segregated for aborted pollen. This is approximately the same frequency of partially sterile plants that Stadler[3] observed following a 250 *r* X-ray dose. The relationship between dosage and number of partially sterile F_1 plants is linear. A high proportion of the structural changes induced in the chromosomes by the mustard appear to be deficiencies. This conclusion is supported by the fact that the linked genes *Wx* and *Sh* usually were lost together, and the transmission rates of the sterility-inducing alterations were low. The small numbers of partially sterile individuals in F_2 families from selfed F_1 partially sterile plants indicate that reciprocal translocations, if present at all in the treated cultures, occurred with low frequency. In this respect the action of mustard on maize differs from that of X-rays[3] and the high energy radiations from the atomic bomb[2]. The latter yield a relatively high porportion of reciprocal interchanges which are regularly transmitted to half the offspring.

In experiments which permitted close regulation of the mustard treatment it was found that the frequency of losses of the dominant effects of marker genes in the F_1 endosperms, was approximately proportional to dosage over part of the treatment range. This rate of loss, however, was not maintained at a higher dosage. The falling off in rate is probably associated with an increased proportion of multiple deficiencies following the more severe treatments which so impair endosperm development that many of the seeds die. Since the losses of the marked endosperm loci themselves would be expected to contribute to the lethal effects, the frequency of kernels showing the specified losses would be expected to decline as the dosage enters the range where multiple chromosome breaks become frequent.

Although losses of the effects of the dominant alleles *Su, Wx, Pr* and *R* characterizing the entire kernel of the order of 12 percent were found in the F_1 endosperms following moderately severe mustard treatments of the pollen, no evidence of increase of losses over the controls was found in the embryos in the same kernels. On the average, the sperms functioning in the generation of F_1 endosperm and embryo, should have been affected alike by the

TABLE III.—Entire and fractional losses of three dominant endosperm characters

Locus	Number of losses		Ratio F/E
	Entire	Fractional	
Su	61	88	1.4
Wx	38	52	1.4
Pr	84	225	2.7

nitrogen mustard. It seems clear that whatever the nature of the initial effect of nitrogen mustard on the chromosomes may be, it does not necessarily lead to breakage or inactivation. Predisposition to certain genetic changes are induced rather than the changes themselves. The primary endosperm cell but not the egg provides conditions favorable for realization of these potential changes. Stadler[3] has commented upon the parallel mutagenic effect of ultraviolet light.

Losses of different dominant marker characters affecting only a portion of the endosperm were 1.4 to 4.0 times as frequent as those involving the whole tissue. Mustard gas, in this respect, is similar to ultraviolet light and unlike X-rays[3]. The preponderance of fractionals might be construed as evidence of doubleness of the chromosomes in the sperm within the mature pollen. This conclusion, however, does not necessarily follow. If actual breakage is deferred until after fertilization, it is conceivable that the chromosome is single at the time of treatment and that potential breaks are not always realized in both daughter strands in the primary endosperm nucleus.

The low frequency of readily detectable point mutations relative to gross chromosomal derangements is noteworthy. The experiments involving marked loci for endosperm characters afford no evidence that the number of gene mutations was increased by the mustard treatment. Among 745 F_2 families in the saturated mustard vapor series, on the other hand, five mutations affecting seedling chlorophyll development were found. Certain of these chlorophyll mutations were transmitted in normal Mendelian proportions. The frequency of occurrence (0.67 percent) was low as compared with 14.5 percent of sterility-inducing chromosomal derangements in the same treated stock. In this regard the mutagenic action of mustard gas on maize is similar to that found by Stadler[3] for X-rays.

The present experiments shed no light on the important further question as to whether the apparent gene mutations are unique in kind or merely small deficiencies.

Summary

1. An apparatus is described by which mustard gas vapor may be applied to pollen in accurately graded doses.

2. Chromosomal derangements leading to partial fertility in the F_1 plants are induced with high frequency in mustard treated pollen. Most of them appear to be deficiencies. Few, if any, reciprocal translocations occur.

3. The relation between dosage of mustard applied to the pollen and frequency of partially sterile F_1 plants is linear.

4. The incidence of readily detectable point mutations relative to sterility-inducing chromosomal derangements is low.

5. Following pollen treatment the number of entire losses of dominant endosperm characters is much higher in F_1 endosperms than in the associated embryos.

6. Fractional losses of different dominant characters in F_1 endosperms were 1.4 to 4.0 times as high as entire losses.

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INHERITANCE OF WHORLS IN COCKER SPANIELS*

A Preliminary Report

TERRY PULLIG

EARLY in 1944 a small kennel of cocker spaniels was established at Louisiana State University by the author for the purpose of investigating the inheritance of some of their characteristics. One of the first obvious variations to occur was a whorl in each flank of the red male No. 13. This male was sold when about four months of age and about two years later his owner wrote the author that the dog was stamping some of his offspring with his "trademark."

Inheritance of Hair-Patterns in Other Mammals

In his work with guinea pigs Castle[2] demonstrated that the rough character was dominant to the smooth character but that certain smooth animals which he called prepotent did produce offspring showing a weakened condition of the rough condition.

In guinea pigs there is a continuous series of variation between the smooth fur and the very rough ones., The work of Castle and Wright[3] showed that the primary effects were due to two independent pairs of alleles. The factor *R* discovered by Castle[2] was essential for the development of the common type of roughness and it was completely dominant over its allele present in smooth guinea pigs; the other, an incomplete recessive, *s*, was necessary for the higher grades of roughness.

In the study of whorls, often called swirls in swine, Craft[4] reported that in the Poland Chinas there was a tendency for the disturbance to disappear in some specimens when they were about twelve weeks of age. Nordby[10] did not observe this tendency in his swine but noticed instead that when the disturbance was small there was a tendency for the defect to be progressively less conspicuous toward maturity. In a red cocker female (author's stock) which did not have a heavy coat the author did not observe any tendency toward disappearance in the flanks but rather that the disturbance remained at about the same proportion from whelping until maturity. On the other hand, in the heavier coated black cocker spaniels the whorls, especially in the flanks, are most difficult to find because of the fact that waves develop in the dense coat on the body and the long coat hangs over the whorls in the flanks.

Nordby[9] found that whorls in swine were heritable but that the particular type of inheritance involved was not simple. Craft[5,6] and Nordby[10] suggested a hypothesis of two interacting dominant factors as a possible explanation for the inheritance of hair whorls in swine.

Brewster[1] published the pedigree of a family showing the occurrence of "double crowns" for three generations and stated that the disturbance was apparently a hereditary character.

In order to study the inheritance of different directions of hair streams in the frontal region of man, Kiil[7] collected data on Norwegian children, twins and families. These data showed that the different types of frontal hair direction in man was brought about by autosomal multiple alleles which were named *d'*, *D''*, and *D'''* (*D''* being recessive to *D'''*). Variations within the three major types might be due to a minor allelomorphic gene series of the major genes or to the nature of inherited modifiers or to both. It was suggested that the genetic factors were of a growth-regulatory nature. Kiil[8] did not observe a single case of his Type III among the 66 mongoloids although the expectation was 16 or 17 cases. This absence, he stated, might be the result of a retardation of growth in the region of the head which normally brings forth this dominant character.

Hair Streams in the Cocker Spaniel

In general the normal hair stream in the cocker spaniel is arranged rather simply. The hair on the head and the spinal column slopes caudally while the hair on the sides of the neck and the sides of the body slopes ventrocaudally. Variations in the direction of the hair stream occur in several regions of the body although the only disturbances which were observed by the author were located in both flanks and on both shoulders. Other breeders of cocker spaniels have reported to the author that they have observed whorls on the head, on the neck, on both flanks and on the left shoulder.

The whorls in the flanks observed by the author in her stock had a center from which the hair seemed to stream in opposition to the normal hair stream. This disturbance was noticeable at whelping in the five puppies in the

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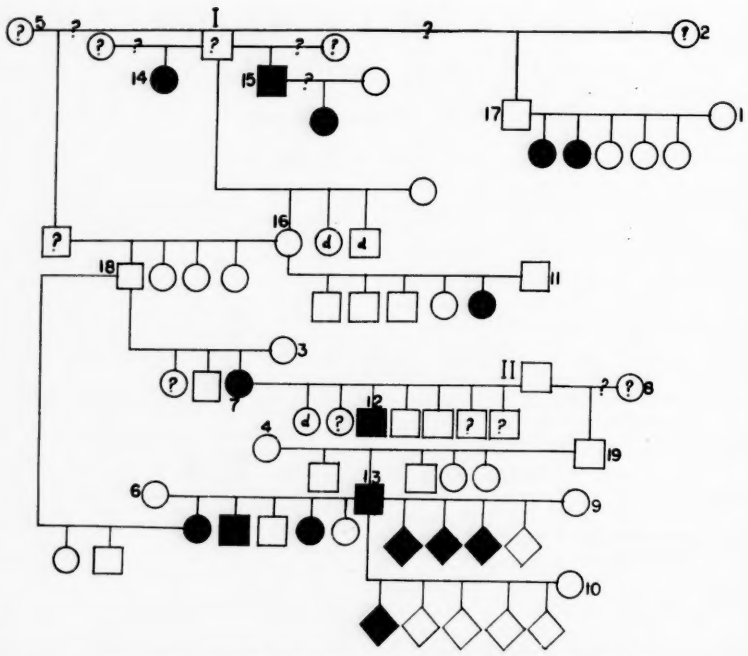


PEDIGREE OF HAIR WHORLS IN COCKER SPANIELS

Figure 7

Most of the animals shown in this pedigree chart are related either to sire Number I (top of pedigree), or to sire Number II (center of pedigree), or to both of them. Whether or not sire I had hair whorls is not known, but sire II did not. Black symbols represent individuals showing hair whorls, and diamonds represent individuals whose sex is unknown.

author's kennels. When these puppies reached a salable age of three to four months, the whorl was still conspicuous and had enlarged proportionately to the size of the individual. Of the five puppies that were sold only one red female was seen after she reached maturity and the whorls in her flanks were still very conspicuous.

Relationship of Animals Involved

Almost all the animals shown in Figure 7 are either related to sire No. I or to sire No. II or to both of them. Female No. 1 is a great granddaughter through her sire as well as a granddaughter through her dam of sire No. I. Female No. 2 is a granddaughter through her sire and a great granddaughter through her dam of sire No. II. Female No. 3 is a granddaughter through her sire of sire No. II but is a great granddaughter through her dam of sire No. I. In the case of female No. 4 her double great grandsire through her sire is also the grandsire of sire No. II through his dam. The grandsire of sire No. I through his sire is also the grandsire of female No. 5 through her sire and her great grandsire through her dam. The grandsire of female No. 6 through her sire is also the great grandsire of sire No. II through his dam. The sire of female No. 8 is the grandsire of sire No. II through his dam. The grandsire of sire No. I through his sire is also the great grandsire of male No. 11 through his dam and the double great great great grandsire through his sire. Even the grandsire of No. I through his sire is also the great grandsire of sire No. II through his sire.

The individuals shown in Figure 8 are even more closely inbred than those in Figure 7. Male No. 1 was mated to his half-sister to produce male No. 2 who was then mated to his half-sister.

The relationship of the animals represented in Figure 9 is unknown as the data were received from breeders present at a lecture on "Principles of Genetics as Applied to Dogs" which was given by the author.

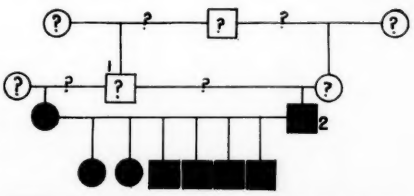
Location of Whorls

No attempt will be made in this paper to determine the factor or factors that play a part in governing the location of whorls in cocker spaniels, but only to point out the different locations in some of the related individuals. It is not known whether sire No. I, now dead for some time, had whorls or not, but he did produce whorls in some of his offspring. His mature buff daughter No. 14 which the author has seen had conspicuous flank whorls like those in red male No. 13, who was a grandson of sire No. II. A breeder contributed the information concerning the red son No. 15 that had the same type of flank whorls as his half-sister No. 14. She stated that in general the male No. 15 produced one or two puppies in some litters which had whorls in their flanks like his, but that the whorls were always on red puppies and never on any of his black offspring. The daughters of female No. 3 and female No. 16, however, are both black. A more extensive study will be required to determine whether or not there is linkage between the factor for red in cocker spaniels and the factor for whorls.

The male No. 17 without whorls, a son of sire No. I, when mated to female No. 1 also without whorls produced two females with whorls in a litter of five females. One of these females had a whorl on her head, while her litter sister had one on her neck. In the case of the black female No. 7, which a professional handler had trimmed to be shown, the owner was told that this animal was difficult to trim properly because of its cowlick. The owner told the author, however, that she had no idea where the location of the whorl was. The author has gone over this female, which has a very dense, slightly wavy coat and there seems to be a disturbance in the hair stream at the upper border of the left scapula. Among the descendents of sire No. I there have been whorls in both flanks, on the head, on the neck, and possibly in the case of female No. 7 related to sire No. I and sire No. II on the upper left shoulder.

Sire No. II has the grandson No. 13 which has whorls in both flanks which in turn produced whorls in the same location when mated to female No. 6 owned by the author. It is believed that the whorls in his other two litters were probably in the flanks because the owner called them "His Trademark." Male No. 12 has a whorl on both shoulders about midway of the anterior edge of his shoulder yet his dam's disturbance is located at the upper dorsal border.

Based on the mating of whorled male No. 13 to female No. 6 without whorls and the mating in Figure 8 in which both parents have whorls, as well as taking into consideration the ratio of the two types of offspring when neither parent has a whorl (Table I) and the ratio of two types of offspring when one parent has a whorl (Table II), it is believed that sire No. II does not have a whorl.



THREE GENERATIONS OF INBREEDING

Figure 8

Here a mating of two generations of half sibs produced hair-whorl individuals all of whose progeny resembled their parents in this respect.

Discussion

A study of Table I shows that the ratio of normals to whorls is the simple Mendelian ratio of 3:1 in which one pair of factors is concerned. Taking into consideration the small number of individuals shown in Table II the ratio 9:7 is close to the expected 1:1 ratio of the mating of recessives to heterozygous individuals when one pair of alleles is under consideration. The mating represented in Figure 8 is what is expected when one pair of factors is concerned in the production of a recessive characteristic. The mating of male No. 18 to the female with whorls produced a male without whorls (Figure 7). This mating eliminated the possibility of a sex-linked recessive character.

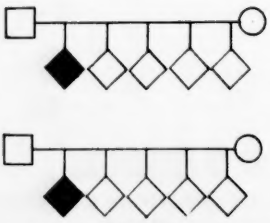
Based on the limited data in this paper the author offers a hypothesis that the whorl is a simple recessive factor that is carried on an autosome. There is a question of linkage betwen this factor and the factor that produces red which was brought out by a statement made by one breeder. If there is linkage it is not com-

TABLE I. Neither Parent Having Whorls

without × without	Normal	Whorls	Unknown
♂ no. 17– × ♀ no. 1–	3	2	
♂ no. 11– × ♀ no. 16–	4	1	
♂ no. 18– × ♀ no. 3–	1	1	1
♂ no. 19– × ♀ no. 4–	4	1	
Fig. 9 ♂♂– × ♀♀–	8	2	
Total	20	7	1

TABLE II. One Parent Having Whorls

One parent with, other without	Normal	Whorls
♂ no. 13+ × ♀ no. 6–	2	3
♂ no. 13+ × ♀ no. 9–	1	3
♂ no. 13+ × ♀ no. 10–	4	1
♂ no. 18– × ♀+	2	
Total	9	7



TWO CASES OF "SPONTANEOUS HAIR WHORLS"

Figure 9

Two cases have been reported to the author of the occurrence of a single hair whorl individual in progenies of five puppies.

plete because there have been black cockers with whorls.

Summary

1. The characteristic of whorls in cocker spaniels is probably an autosomal recessive factor.

2. The letter *w* is suggested for this recessive gene and *W* for its dominant allele.

3. The data are insufficient to draw any conclusions as to whether *w* is linked to the non-extension factor, *e*, which is present in red cocker spaniels.

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Forage Crops

THE first three chapters of the book* deal with history, geography, and the influence of climatic and soil factors upon the growth of forage crops. The next nineteen chapters deal individually with hay and silage crops or groups of related forage crops. The discussions and materials presented are based on technical and popular publications.

The form of presentation reflects the author's special training and preparation for teaching in agricultural education. The subject matter is easy to read and understand. The information is well organized, logical in arrangement, precise, but elementary. The book should be especially suited to agricultural students in high school and beginning agronomic courses in college.

The last nineteen chapters deal with such phases as forage mixtures, seeding of grasses and legumes, forage processing, grassland farming, and the usual concluding chapters in text books and crop production bulletins on plant pests, insects and diseases.

The book should prove to be a valuable reference for students in agronomy. The author states in the Preface that an effort has been made "to embody in a comprehensive manner, the facts and fundamentals associated with the production of hay and silage crops," and adds further that "Data—have been presented to substantiate the principles and fundamentals as discussed." In this respect the book is a disappointment, as are most text books dealing with crops. Little consideration is given to the principles of genetics, ecology, physiology, etc., as subject matter in the text. In this instance the discussion of fundamentals is limited to approximately ten pages in the third chapter. Without such treatment there is little likelihood that the student would be stimulated to give serious thought or future study to the fundamental aspects of crop production.

The book has good paper, it is attractively bound, and the printing and reproductions are fair to good. It is a great improvement in method of presentation, readability, and clearness, other than the lack of fundamentals referred to above, over most of the texts during the past quarter of a century.

O. S. Aamodt

Bureau of Plant Industry

**Forage Crops.* Gilbert H. Ahlgren. McGraw-Hill Book Company. New York City. 1949. 418 pp. $5.00.

STUMPY, A RECESSIVE ACHONDROPLASIA

In Shorthorn Cattle

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STUMPY CATTLE
Figure 10

Two views of one "stumpy cow" are shown (upper left and below). The cow is about three years old and in the last picture is shown with her normal calf produced when she was mated to a normal bull. The poor condition and the absence of a switch on her tail are typical of the stumpy animals. The other view shows a two-months old "stumpy" calf showing the curly coat and the overgrowth of tissue around the head of the hoof. At this age stumpy calves are about three inches shorter than normal animals. They shed their winter coats more slowly than normal shorthorns.

ABOUT ten years ago dwarf calves began appearing in a purebred Shorthorn herd in Central Nebraska. The breeder had been following a rather intensive line-breeding program, and it soon became evident that the dwarf or "stumpy" condition was genetic in nature. The affected animals have three distinguishing characteristics in common: (1) They

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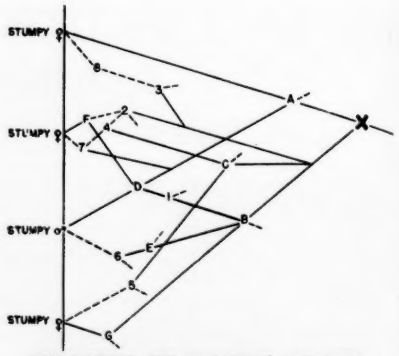
have a curly coat, making it possible to detect stumpy individuals at birth. The switch is smaller than normal, both in amount and length (Figure 10). (2) They exhibit an achondroplastic condition. This is more apparent in the forelegs than in the hind legs, since the knees are enlarged and the cannon bone appears slightly twisted laterally, making the animals seem somewhat bowlegged. There is an enlargement at the hoofhead and the foot is often turned outward. Body length appears to be normal and the head does not seem to be deformed. (3) Since most of the affected animals are thin, there seems to be a metabolic disturbance which becomes more pronounced as the animals mature. At birth they appear in fair condition, but as they mature they fail to put on the usual amounts of fat.

Gregory *et al*[2], and Gilmore[1] have discussed the general types of achondroplasia that have been reported in cattle. It would seem from these discussions and from Lerner's[3] check list of lethal and sub-lethal characters in farm animals, that at least four or five different genes are involved. These genes are either lethal or sub-lethal in their action.

The present cases seem to be caused by a gene that differs from those previously discussed[1,2,3]. The animals reported on in this paper live and can reproduce. In this respect they resemble the dwarf Herefords and Jerseys that have been reported by Lush[4] and Mead *et al*[5].

Although the present condition is not lethal, it is of economic importance to the breeder. In the first place, there is a direct economic loss to the breeder, since the affected animals cannot be used for replacement stock, nor can they be sold for slaughter as profitably as normal animals. In the second place, and this is probably more important in the long run, the sale of breeding animals is hindered. It does not take long for the reputation of a purebred breeder to be hurt by the appearance of undesirable "off type" animals in his herd.



PEDIGREE OF STUMPY CALVES

Figure 11

Typical pedigree of four of the stumpy calves reported in this study. All of them trace to "Bull X" in at least two lines.

Stockard[6] states that achondroplasia has been found in most vertebrates, including man. The achondroplastic condition seems to be occasioned by a malfunction of the pituitary gland during a portion of the prenatal development period. This malfunction may or may not involve the thyroid gland. The physiological processes involved in the production of "stumpy" calves have not been studied. No post mortem examinations have been made nor has it been possible to obtain body measurements. The data presented in the following discussion are based entirely on the phenotypic appearance of the animals and on the study of their pedigrees.

The herd in which the present cases of achondroplasia were found has been rather intensively linebred for about fifteen years. The first "stumpy" calf on which a definite record is available was dropped in 1937. Of the 562 calves born between 1937 and 1946, 26 have been dwarfs. The incidence of dwarfs in the entire herd for this period has been 4.6 percent.

Since 1937, 21 bulls have been used in the herd. Of these, eight have produced "stumpy" calves. The affected calves have been produced by 20 cows. Many of the cows and bulls have but one or two calves to their credit, so it is not known if they are carriers. Ap-

parently, however, many of the breeding animals are normal and do not carry the gene.

Most of the affected animals were sired by Bull A, or trace through one or more paths directly to him. A paternal half-brother of Bull A also appears as the sire in several pedigrees. Both of these bulls were sired by Bull X, who was a grandson of Ceremonious Sultan. The relationship between the sires and dams of four of the "stumpy" calves is shown in Figure 11. The pedigrees for only a portion of the calves are given in order to keep the chart relatively simple.

It has not been possible to determine just when this mutation occurred in the Shorthorn breed. The Bull X is definitely implicated for the majority of the affected calves trace directly to him. A few calves, however, were from dams who do not trace to Bull X. These cows and Bull X do have a common ancestor in Whitehall Sultan.

One "stumpy" calf dropped in 1939 was sired by a bull that was unrelated to any of the other animals in the herd. He traces to several imported animals and it has not been possible to trace his ancestry beyond this point. Unless there was a mistake in recording the breeding of the cow, this one calf suggests the widespread presence of the "stumpy" gene among Shorthorns, another occurrence of the mutation, or some cause other than the gene responsible for the remaining calves.

Table I shows the results of the matings of those cows and bulls that have produced at least one "stumpy" calf. The condition is not sex-linked, since fourteen heifers and twelve bull calves have been produced.

From Table I it is seen that the heterozygous matings have produced "stumpy" calves in an almost perfect 3:1 ratio. It is concluded, therefore, that the "stumpy" syndrome is caused by a single autosomal recessive gene.

TABLE I.—Matings Producing "Stumpy" Calves

Mating	Normal	Stumpy
All bulls and cows	536	26
Bulls siring stumpy calves × all cows	411	26
Cows producing stumpy calves × all bulls	95	26
Known heterozygous matings	74	26

This conclusion is borne out by the appearance of "stumpy" calves in a neighboring herd of grade Shorthorns. A son of Bull A was used in this herd several years ago. When the offspring of this son were mated with a sire closely related to Bull A, several "stumpy" calves were produced. One of these, a heifer, was saved and mated to an unrelated bull. She calved for the first time in 1946 and had a normal calf. The cow and calf are shown in Figure 10.

It appears that the mutation occurred as far back as Whitehall Sultan and was transmitted in the gametes produced by him. The mutation responsible for this gene, however, might have occurred in a remote ancestor. Since it is a simple autosomal recessive, it might have been carried in a heterozygous condition for some time before it appeared, or before a breeder became suspicious of the appearance of dwarf calves in his herd. Probably little attention is paid to the appearance of the small number of dwarf calves encountered in most herds under usual breeding programs.

Summary

A non-lethal type of achondroplasia found in Shorthorn cattle has been described. In addition to the achondroplastic condition, the animals all have a curly coat and all seem to exhibit some metabolic disturbance. They are thinner than normal animals of the same age that receive comparable feed.

From the analysis of the pedigrees, it is concluded that the syndrome is caused by a single autosomal recessive gene.

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A GENETIC RESPONSE TO INDUCED GOITER IN CHICKENS*

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As our knowledge of the functions of the endocrine glands is expanded, it becomes increasingly apparent that the activity of the thyroid gland influences economic traits of poultry. During the course of research in this laboratory on the effect of induced goiter on the genetics of growth[1], a marked difference was observed among 51 dams' families in their response to thiouracil.† There was as much as a 46-fold enlargement in the thyroids in some families while in others the enlargement was only 3-fold.

Hereditary factors which cause susceptibility to goiter under natural conditions are known in several species of animals including man.[2] One or more genes are apparently involved in the susceptibility of pigeons and doves to goiter[3]. However, as far as the writers are aware, no report has been published on the occurrence of genes that produce goiter in chickens either under natural or induced conditions.

Materials and Method

During the fall of 1949 a total of eight New Hampshire males were artificially mated to groups of seven to nine hens each. The offspring of these matings, designated here as the first generation, were raised under identical conditions on a mash containing 0.2 percent thiouracil. After the birds were ten weeks old, they were killed and the thyroid glands were dissected and weighed to the nearest centigram.

All families being represented, part of the birds from an early hatch were fed a normal mash. After killing and dissecting the treated birds, the mean thyroid weight of each dam's family was calculated. Using this mean as a criterion, selection for large and small thyroid size was made on a family basis within the birds raised on the normal mash (i.e. without thiouracil). Seven pullets and four cockerels were selected from the families, which showed the greatest thyroidal enlargement from thiouracil, while six pullets and four cockerels were saved from those families with the least response.

In the summer of 1950, the selected birds of each line were artificially mated. This intraline mating yielded two hatches. The offspring of both lines were raised together under identical managemental conditions and were fed a mash containing 0.2 percent thiouracil. After the fourth week of age, all the birds of the second generation were killed and the thyroid glands were dissected and weighed.

TABLE I.—The mean thyroid weights of two lines of chickens selected for a high and low thyroidal response to thiouracil

Lines	First generation* Number birds	First generation* Mean thyroid wt. in centigrams	Second generation† Number birds	Second generation† Mean thyroid wt. in milligrams
High	35	296.9	53	161.8
Low	25	81.8	44	95.7

*Birds ten weeks old.
†Birds four weeks old.

TABLE II.—Analysis of variance for thyroid weight of the first generation fed thiouracil from day-old and killed at ten weeks of age

Source of variation	Degree of freedom	Sum of square	Mean square	F value
Total	60	168.67		
Between lines	1	68.99	68.99	41.56*
Between hatches	3	6.86	2.29	1.38†
Error	56	92.82	1.66	

*Highly significant (theoretical F = 4.02 and 7.12).
†Insignificant (theoretical F = 2.78 and 4.16).

TABLE III.—Analysis of variance for thyroid weight of the second generation fed thiouracil from day-old and killed at four weeks of age

Source of variation	Degree of freedom	Sum of square	Mean square	F value
Total	96			
Between lines	1	104955	104955	12.706*
Between hatches	1	11844	11844	1.434
Error	94	776447	8260	

*Highly significant (theoretical F = 3.946 and 6.918)

*Scientific Paper No. A290. Contribution No. 2238 of the Maryland Agricultural Experiment Station (Department of Poultry Husbandry).

†Thiouracil was furnished through the courtesy of Dr. Mark Welsh, Lederle Laboratories, Pearl River, N. Y.

Results and Discussion

The average of the thyroid weights of 51 dams' families was 1.82 grams, ranging from 0.46 to 5.28 grams. The mean thyroid weight for each line in the two generations is given in Table I. The analysis of variance of the data is shown in Tables II and III. In this analysis, the variance caused by different hatches was subtracted from the error variance. This was done in order to eliminate environmental variation caused by securing parts of the population of each generation at different time intervals.

Table II shows that a very highly significant difference existed between the mean thyroid weights of the full-sibs of the parents of the second generation. This difference, however, was due to the fact that the analysis was confined to the families from which the prospective parents of the second generation were selected. In Table III it will be noted that the progeny of the previously selected parents continued to show a highly significant difference in their thyroid weights. This is a conclusive evidence that it is possible to establish by selection two lines of chickens which differ with respect to their goiterous capacities. Hence it must be concluded that the capacity of the chicken to produce enlarged thyroid gland is under genetic control. The number of gene pairs and the mode of inheritance cannot be determined until the two lines are completely established.

Summary

It was possible to select lines of chickens that show a wide variation in the enlargement of the thyroid gland under conditions of induced hypothyroidism proving that this trait is under genetic control.

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PHOTOGRAPH OF A MAN WITH A TAIL

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THE photograph (Figure 12) was recently given to the writer by his old friend K. I., a university graduate who served for several years as an agriculture directing official in the local government of Formosa. K. I. obtained this picture in 1917 while he was in Luzon, Philippine Islands. It is a reprint of an original taken by a certain E., a Japanese businessman with whom K. I. had become acquainted.

A few years previously, E. had been staying in the home of a native of the Igorot tribe in a village not far from Baguio. He became quite friendly with the family. During his stay he found that the man in the family had a tail. One day E. succeeded in persuading the man to let him take a photograph showing the tail. This photograph was shown to K. I. who took an interest in it, and made a reprint. This reprint, a negative, was preserved until recently, and was finally given to the writer. Any further information regarding this tailed man is lacking, though he appears an adult about thirty years old, and the tail looks fairly long and rather thick and stiff. Although there are some photographs of tailed babies published in literature, i.e., Harrison[2] and Schwarz*; those of tailed adults are rare. This writer has never seen any*. K. I. remembers that S. told him at the time that men with tails

*Except the one in 'Gesammelte Werke von Robert Koch', Leipzig, 1912, Vol. 2, P. 822. This is an engraving after a photograph of the buttock of a Hindu lad from the Bonnia cast, about seventeen years old. The tail somewhat resembles that of the Igorot man. The photograph had apparently been taken in 1871, and was given to Koch during his trip to India. Koch brought it back to Berlin, together with a photograph of a tailed Hindu child (reproduced on the same page). Koch gave these photographs to Virchow, who exhibited them at the meeting of the Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte on May 17, 1884.

TAILED IGOROT
Figure 12

This photograph was made many years ago in the Philippines. According to reports, in this particular Igorot tribe, the birth of tailed babies was by no means uncommon. It appears that the Dyaks of Borneo also display the same tendency.

were not rare among that particular tribe of Igorot.

After the writer published this photograph in a Japanese popular journal, he received a letter from a reader named M. S., stating that he had seen a tailed man among the Dyaks in Borneo. On further inquiry, M. S. told the writer that he served from 1942 to 1945 as the overseer of the rubber plantations at Boenoet and Poetoessibau, Dyak villages situated near the upper stream of the River Kapuas in the Province of Sintang in West Borneo. During this time, he gave medical treatment to the natives at their request, though he was not a doctor. Thus he had the opportunity to make physical examinations of many of them. One day he found among his patients, a man from thirty to forty years of age who had a tail. The tail was about 7 cm. long, 2 cm. thick, hairless and wrinkled. M. S. tried to make a closer examination of the tail, but the native refused to allow it, since his companion laughed and teased him. These natives told M. S. that there were some others in the neighborhood having similar tails. He also heard that other Indonesian tribes speak of the Dyaks as ape-like, because many of them are tailed.

In the literature there are many records of tailed men. Bartels[1] published a comprehensive summary of such records which he was able to collect from the literature. In all there are 116 cases consisting of 52 males, 16 females and 48 of unrecorded sex. Schäffer[3] reexamined these records, and added to them those published since 1884. He has thus listed 92 cases which he thought relatively authentic. In Bartels' paper there are also a great many references to legends and travelers' reports relating to tailed men. Among them, those on the Dyaks are among the outstanding ones. According to Bartels[1], reports on such people among the Dyaks appear in travelers' reports in the Seventeenth Century. The reports by Koebel especially, are very positive and clear. He assures the reader in all his three successive publications of the presence of tailed men. (1841, 1843 and 1858.) He states that there are many Dyaks, both male and female, having tails. For instance, among the villagers of the town of Scharabas, (ten to fifteen miles from Pontianak), there are some twenty tailed people of both sexes. There is thus a fairly good coincidence between the old record and the recent report.

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PYGMY, A DWARFING GENE IN THE HOUSE MOUSE

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IN the course of his selection of mice for small size, MacArthur[3] noticed that certain matings produced a proportion of undersized animals or "runts." These individuals were noticeably smaller than their normal sibs at 12 days and their growth was so retarded that, at 60 days, they were less than half the weight of normals and seldom weighed more than 9 gm.

In 1948, Professor MacArthur kindly sent Dr. Falconer of this laboratory some of his selected small mice to form the basis of another "Small" stock. In addition, mice of the highly inbred C57 (black) and Strong-A strains were used as foundation animals. Two matings in the third generation of selection for small size produced a few animals distinctly smaller than their litter-mates and agreeing with the description of "recessive-like runts." The present author is indebted to Professor MacArthur for permission to investigate this condition further.

MacArthur's suggestion that these "runts" were produced by a recessive gene has been vindicated. The homozygote, the "runt," is sterile, but matings between heterozygotes have produced the expected proportion of "runts." Further, the condition can be recovered after outcrossing to various other stocks. Having established that these "runts" were produced by a mutant gene, it seemed desirable to give the gene a definitive name, and to reserve the name "runt" for cases of undersized animals due to unknown causes. The name "pygmy," symbol *pg*, is proposed.

This is the third hereditary dwarfism to be reported in the house mouse. Snell[5] reported a form which subsequently proved to be due to an anterior pituitary deficiency and, more recently, Strong[6] has described the occurrence of a hereditary dwarfism in the descendants of mice treated for many generations with methylcholanthrene, a carcinogenetic agent.

Genetics

Those matings in the Small stock which have produced pygmies have given a total of 331 normals to 105 pygmies when scored at 21 days. To test the goodness of fit to a 3:1 ratio a correction must be made for the bias introduced by the automatic exclusion of matings between heterozygotes which, by the chances of sampling, produced no pygmies. The average number of progeny per mating is 15.6 so that an approximate correction can be made by using

$$\tfrac{1}{4} \times \frac{1}{(1-(\tfrac{3}{4})^{15.6})}$$

as the expected proportion of pygmies, and then using a χ^2 test.

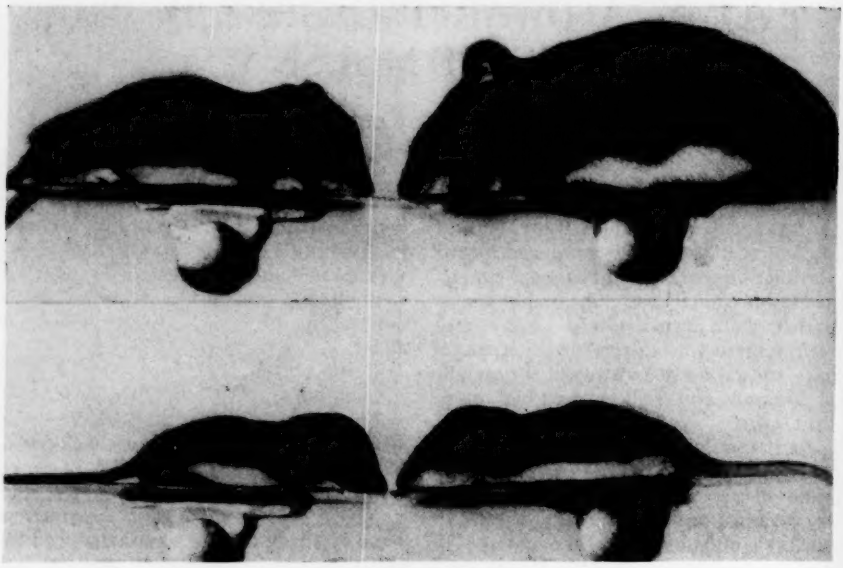
	Normal	Pygmy	Total
Observed	331	105	436
Expected	325.8	110.2	
Deviation	5.2	5.2	

($\chi^2_1 = 0.33$ $P > 0.5$)

The deficiency of pygmies, though not statistically significant, is probably real as some animals diagnosed as pygmies at 12 days died before 21 days, when all were finally scored. No estimate of the viability can yet be made because the data are too meager. It seems that deaths are due more to the inability to compete with their much larger litter-mates than to any inherent weakness.

Heterozygotes from the Small stock were outcrossed to stocks of large mice and also to various inbred lines. Intercrosses were set up from the progeny of these matings and some produced pygmies which segregated in a

*Recipient of an A.R.C. Training Grant. The author is indebted to Dr. D. S. Falconer for help at all stages of this work.



PYGMY AND NORMAL MICE

Figure 13

A photograph of pygmy and normal littermates from the Small stock. Pygmies are shown on the left, and normal mice on the right. Adults are above, and those less than twelve days old are below. Approximately natural size.

clear cut manner. These intercrosses have produced a total of 251 normals to 76 pygmies. The expectation is corrected as before for the average number of progeny per mating.

	Normal	Pygmy	Total
Observed	251	76	327
Expected	243.0	84.0	
Deviation	8.0	8.0	

($\chi^2_1 = 1.03$ $P > 0.3$)

There is no indication that the recognition of pygmies is dependent on the genetic milieu of the Small stock. When the two sets of data given above are compared in a 2×2 contingency table they give a χ^2 for 1 d.f. of only 0.07 ($P > 0.7$).

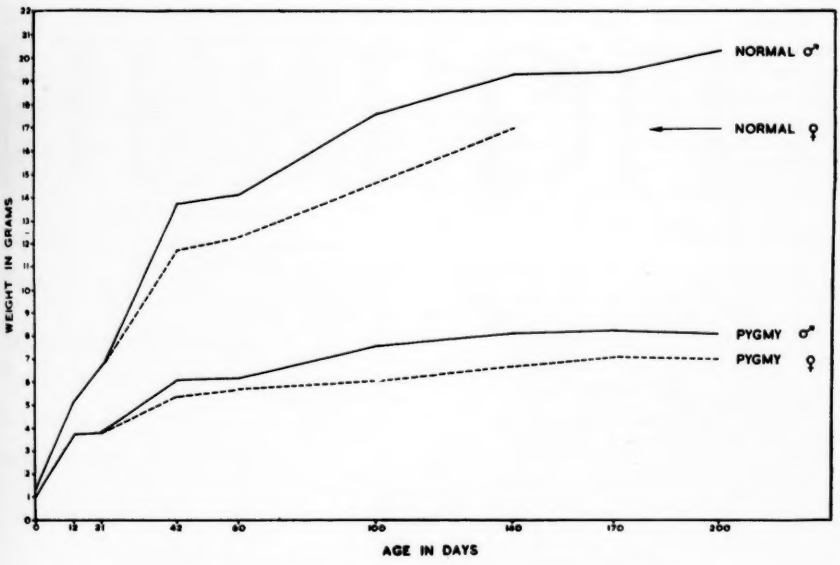
The gene pygmy (*pg*) has been tested for identity with Snell's dwarfism (*dw*). Through the kindness of Professor T. Kemp a male heterozygous for Snell's dwarfism was obtained. This male (genotype $+/dw$) was mated to two females both proven heterozygous pygmy (genotype $+/pg$). These two matings produced 16 to 20 progeny respectively, none of which was noticeably smaller than its sibs. Since, if the two genes were identical, the probability of obtaining no homozygote in a progeny of 36 is only $(3/4)^{36}$ or 0.000032, it must be concluded that the two genes are not identical.

It has not been possible to test pygmy for identity with Strong's hereditary dwarfism. Phenotypically, however, the two conditions seem quite distinct since Strong reports that two of his dwarfs were mated together and produced two litters, whereas pygmies are sterile in both sexes.

Description

The growth pattern of pygmies differs considerably from that of Snell's dwarfs. The latter cannot be distinguished with any certainty before 12 days, although Francis[2] could trace the retardation in growth back to four days. Pygmies on the other hand are markedly smaller than normals at birth. Their identification at this age, however, is not certain as the birth weights of pygmies and normals overlap.

By about four days the pinna of the ear has become free and has flattened out. At this age the relatively smaller size of the pinna in pygmies provides an additional and more reliable criterion for classification. By twelve days the difference in ear size is pronounced and classification on this basis is easy and certain (Figure 13).



GROWTH CURVES OF PYGMY AND NORMAL MICE

Figure 14

Compound growth curves of pygmies and normals from the Small stock. Weighed at the ages shown on the graph.

Growth Curves

The growth of pygmies follows a very similar course to that of normals, though at a much reduced rate (Figure 14). A noteworthy feature is the negligible increase in the average weight of pygmies from 12 to 21 days. This stationary period can probably be ascribed to the intensity of competition with normals for milk. Daily weighings of individual pygmies in litters which were progressively reduced in size to give them more milk, showed a steady increase in weight over this period. This is unlike the definite loss in weight shown by Snell's dwarfs in the period 17 to 25 days which Boettiger and Osborn[1] found to be independent of the nutritional status.

The adult pygmy differs in proportions as well as size from a normal mouse (Figure 13). Relative to the body length, the ears are short, the feet rather short and the tail long, as reported by MacArthur and Chiasson.[4] The coat appears to be as long as that of normals and so appears relatively longer. It is kept well groomed so that the general appearance is that of a sleek, streamlined animal. Quite unlike Snell's dwarfs, adult pygmies are at least as active as normals. Aided by their small teeth, they quite often demonstrate their activity by enlarging the ventilation holes of the aluminum cages in which they are kept, and so escape.

Both sexes have so far proved to be sterile, but the cause of the sterility is not known. In the male, the testes are small and do not always descend into the scrotum. Most males develop priapism, usually by the age of six weeks. This priapism does not seem to be correlated with the descent of the testes. A few males have been obtained with descended testes and without priapism, but their sexual activity has not been observed to pass the stage of interest in oestral females.

Pygmy females have open vaginae, often showing traces of blood. The uterus and ovaries are small, but the latter contain ripening follicles. There is evidence of an irregular oestrous cycle. A normal male, known to be fertile, has copulated with several large pygmy females and produced vaginal plugs, but none of the pygmy females showed any signs of pregnancy.

Further experiments are being made with the object of finding the physiological basis for the dwarfing and sterility of pygmy homozygotes.

Summary

1. Undersized animals segregated in a stock of mice derived from MacArthur's selected small mice. These "runts," in MacArthur's terminology, are produced by a recessive gene which has been given the name *pygmy*, symbol *pg*, to preserve the usual sense of the word "runt."

2. The gene pygmy is not allelomorphic with Snell's anterior pituitary dwarfism.

3. Pygmies differ phenotypically from Strong's hereditary dwarfism.

4. The growth and adult features of pygmies are described.

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THREE RECURRENCES OF MUTANTS IN THE HOUSE MOUSE

THREE spontaneous mutations at known loci in *Mus musculus* have recently occurred at this laboratory. Two, which occurred in parallel sublines of the Strong CBA standard strain, have been identified with pink-eyed dilution, *p*, and short-ear, *se*.[3] The third, a tailless mutation which occurred in genetically heterogeneous material, has been identified with brachyury, *T*.[2] A previously unsuspected *t*-series lethal has since been shown to be present in the stock and was carried by the original mutant animal, causing the tailless phenotype.[1]

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